

CHAPTER 11

INSTRUMENTATION AND CONTROL SYSTEMS

11-1. General instrumentation and control design

Redundant systems and equipment shall be used in the instrumentation and control systems. Automated control data processing/display shall be considered in order to enhance operability. The logic system shall contain redundant central control units: one active and the second one in a hot standby mode. An automatic shutdown override capability shall be designed into the control system to permit the operator to bypass controls that normally initiate automatic shutdown. Control systems and instruments may be pneumatic, ac or dc electrical, electronic digital, combination pneumatic and electronic, or hydraulic. Mechanical-hydraulic and electro-hydraulic systems shall be used in conjunction with governor speed control systems. Pneumatic controls shall not be used on power systems.

11-2. Supervisory control and data acquisition system

The control system shall consist of a Programmable Logic Controller (PLC) based Supervisory Control and Data Acquisition (SCADA) system. Input/output (I/O) modules located in Remote Terminal Units (RTUs) shall provide the interface between the central control unit and other system hardware such as circuit breaker position indication and control, generator paralleling switchgear, automatic transfer switches, UPS units, etc. Man-machine interface (MMI) software shall run on a Windows based PC and interface with the central control unit.

11-3. Power loss and restoration

When the C4ISR facility is operating solely on commercial power, loss of commercial power shall cause automatic disconnect of all loads from the utility bus and initiation of the sequence to bring generator sets up to their full capabilities. Then loads shall be incrementally added to the power plant bus. The sequence and restoration priority for feeders serving technical loads, as well as consideration of the maximum time to restore the service, shall be determined by the using government agency. The central plant operator shall have an option for manually initiating the start sequence, bringing additional generators on-line, or reconnecting the power plant bus to commercial power and returning the generator sets to the condition existing prior to the loss of commercial power. Manual startup and shutdown control shall be provided locally in each generator area for use by an operator-maintainer. Visual and audible alarms shall indicate out-of-tolerance conditions, and critical information shall be printed out or otherwise recorded. This requirement includes minor discrepancies which, if left uncorrected or allowed to degrade further, could result in shutdown of the power-generating unit.

11-4. Automatic control functions

Table 11-1 lists required automatic control functions and their initiation mode(s). These functions are the minimum required, and others may be added as needed. Those functions requiring manual initiation are noted as (M), those initiated by automatic signal are noted as (A), and those operating on a continuous signal are noted as (C). Manual control shall be provided on automatic control functions, as required, for maintenance and testing.

Table 11-1. Automatic control functions

	FUNCTION DESCRIPTION	
	Module or Unit Functions	
1	Generator set startup sequence	A, M ¹
2	Synchronizing generator to main bus	A, M ¹
3	Generator set normal shutdown sequence	M
4	Generator set emergency shutdown (except when in run-to-destruct mode)	A
5	Generator voltage regulation	C
6	Engine speed regulation	C
7	Motor-generator set starting sequence	M
	Power Plant Functions	
1	Real load division between generator sets	C
2	Reactive load divisions between generators	C
3	Bus voltage regulation	C
4	Bus frequency regulation	C
5	Bus frequency time-error correction	C
	Cooling Equipment Area Functions	
1	Shift to backup pump upon failure of any manually or automatically selected pump	A, M
2	Control makeup water feed pump by liquid level	A, M
	Station Service Functions	
1a	Air-conditioning system shutdown upon high temperature signal from critical components	A
1b	Air-conditioning system shutdown upon loss of refrigerant	A
1c	Air-conditioning system thermostatic control of each system	A
2	Compressed air system - maintain station service receiver at rated pressure	A
3	Sump pumps	A
4	Direct current supply - maintain rectifier at rated output	A

¹A - Automatic initiation; M - Manual initiation; C - Continuous signal

11-5. Control room (CR) instrumentation

For C4ISR installations with a large central power plant, on-site instrumentation and controls shall be provided in the CR to centralize operation of the on-site utilities. Instrumentation in the CR shall be microprocessor-based systems and shall permit the power plant operator to monitor the operating status of all equipment, operate the equipment, and evaluate system conditions affecting delivery of electric power and coolant to the site equipment and the facility. Additionally, monitoring and control of auxiliary equipment and of all equipment required to regulate the environment of the site shall be performed in the CR. Operators shall be able to measure operating conditions, which shall permit analysis of the thermodynamic and mechanical performance of the power plant on a continuous basis. Abnormal incipient failures and failure conditions shall be annunciated in the CR. Mimic status boards and/or CRT color graphic displays shall indicate, by color coded groups arranged graphically, the status of all power generation equipment, commercial power primary substation medium-voltage switchgear, coolant pumps, and other critical items. Printout on a periodic basis and under alarm conditions shall be provided for all critical equipment and plant conditions. Remote CRTs and printouts shall be provided for operation officers or the facility engineer.

a. A master frequency control system shall be provided for the primary switchgear main bus. Provisions shall be made for sensing and controlling any or all of the buses when they are electrically connected to each other, when they are in service but electrically separated, or when only one is in service. The system shall be capable of being switched in or out of service, to either side of the primary double bus, or to split bus operation without causing system frequency deviation beyond the requirements specified in paragraph 10-5.b.(4). The system shall include the following.

- (1) Frequency recorders
- (2) Frequency deviation transducers
- (3) Master frequency standard
- (4) Governor actuator devices

b. A master voltmeter recorder system shall be furnished to indicate and record the line-to-line voltages on the main buses and on each medium-voltage power supply bus. The voltmeter shall measure the true RMS voltage. A multi-channel recorder shall be used to precisely record all bus voltages.

c. Recording watt-hour meters and demand meters shall be installed for the commercial power connection. The installation shall meet the requirements of the serving utility and local regulating agencies, and shall provide the Government with data needed to confirm billing by the utility company. Voltage and current measurements shall be true RMS.

d. Table 11-2 lists the minimum requirement for the CR control panel instruments and controls for prime movers. These instruments and controls are the minimum required, and others may be added as needed.

11-6. Instruments and controls for power generation equipment

The prime mover control panel shall be located in the unit control compartment or other suitable space in accordance with the manufacturer's standard design. Table 11-3 lists the minimum monitoring and control functions required of the prime mover control panel. These monitoring and control functions are the minimum required, and others may be added as needed.

11-7. Local instrumentation

Local control shall be provided. Transfer of control to the local station shall be accomplished at the local station upon receipt of permission from the CR operator; the transfer shall be alarmed in the CR. Representative functions to be controlled locally are listed in table 11-4. These functions are the minimum required, and others may be added as needed.

11-8. Transient protection, grounding, bonding, and shielding

Functional upsets shall be minimized by the appropriate use of redundant data transmission codes and software checks. Damaging upsets shall be minimized by the proper use of transient protection devices in all power supplies and on all data communication lines.

Table 11-2. Minimum CR control panel instrumentation for prime movers

	INSTRUMENTATION DESCRIPTION
1	Pressure indicator, fuel oil, supply to engine
2	Pressure indicator, fuel, from main storage tank
3	Level indicator, fuel, main storage tank
4	Level indicator, fuel, day storage tank
5	Pressure indicator, lube oil, supply to engine
6	Pressure indicator, lube oil, supply to turbocharger
7	Level indicator, lube oil, sump tank
8	Pressure indicator, combustion air, turbocharger
9	Pressure indicator, combustion air, filter downstream
10	Temperature indicator, each cylinder and combined exhaust (selector switch)
11	Pressure indicator, starting air, air receiver
12	Pressure indicator, cooling water, pump discharge
13	Temperature indicator, cooling water, supply to engine
14	Temperature indicator, cooling water, return from engine
14	Level indicator, jacket water, surge tank
15	Level indicator, jacket water, surge tank
16	Motor control switches, jacket water pumps, cooling tower fans, fuel oil transfer pumps, centrifuges and related auxiliaries
17	High engine oil temperature
18	Annunciator alarms, low lube oil pressure, high lube oil temperature, low jacket water pressure, high jacket water temperature, high and low day tank levels

Table 11-3. Monitoring and control functions of engine control panel

	FUNCTION DESCRIPTION
	Control Switches
1	Master operation selector (remote-auto-crank-fire-oil)
2	Load selector (base-peak)
3	Master control (stop-start)
4	Fuel selector switch
5	Emergency trip push button (to shut down engine and open generator breaker)
	Motors and Indicators
1	Tachometer
2	Exhaust temperature
3	Set point
4	Control system voltage
5	Digital temperature indicator with selector switch (or recorder) (12 points minimum)
6	Base operating hours
7	Peak operating hours
8	Total operating hours
9	Fuel flow integrator
10	Counters for fast, manually initiated, fired, and total starts
11	Indicating lamps to show start sequencing
12	Relays, timers, and other devices as required

Table 11-4. Functions to be controlled locally

	FUNCTION DESCRIPTION
1	Startup/shutdown prime mover-generator (permissive, manual initiate sequence)
2	Trip prime mover-generator (emergency - CR and local)
3	Trip primary feeder switchgear circuit breakers (emergency - CR and local)
4	Start motor-generator set, if applicable (permissive, manual initiate sequence)
5	Trip motor-generator set, if applicable (emergency - CR and local)
6	Initiate startup, operation, and shutdown of refrigeration compressors
7	Startup and shutdown all air-handling units
8	Start and stop air compressors
9	Cool and heat each pump or bank of pumps and at each motorized valve or bank of motorized valves for equipment startup and shutdown; permit an operator-maintainer, upon approval of the power plant operator, to put alternate equipment in service for the purpose of maintenance, repair, or replacement
10	Temperature indicator, each cylinder and combined exhaust (selector switch)
11	Pressure indicator, starting air, air receiver
12	Pressure indicator, cooling water, pump discharge
13	Temperature indicator, cooling water, supply to engine
14	Temperature indicator, cooling water, return from engine
15	Level indicator, jacket water, surge tank
16	Motor control switches, jacket water pumps, cooling tower fans, fuel oil transfer pumps, centrifuges and related auxiliaries
17	High engine oil temperature
18	Annunciator alarms, low lube oil pressure, high lube oil temperature, low jacket water pressure, high jacket water temperature, high and low day tank levels

- a. Transient protection devices such as fuses and circuit breakers shall be used to limit current in power supplies.
- b. Grounding of the instrumentation and control system shall be in accordance with paragraph 10.16.
- c. Electronic circuits sensitive to EMI shall be protected by filters and electrical shields. Metallic shields shall be used as necessary to protect individual components, transmission lines, equipment installations, or entire buildings to reduce the strength of incident radiated electric and magnetic fields. Filters shall be placed on communications, control, and power circuits to reduce electrical transients to levels that sensitive circuits can endure without causing functional or damaging upsets.